

Brian J. Drouin
Research Scientist – Jet Propulsion Laboratory

Professional Experience

Jet Propulsion Laboratory (1999 – present)

Group Supervisor, Laboratory Studies and Atmospheric Observations (2015-present)

Research Scientist, Earth and Space Sciences Division (2005- present)

Scientist, Earth and Space Sciences Division (2001–2005)

Editor, Journal of Molecular Spectroscopy (2010-2014)

Member of HITRAN steering committee (2010-present)

Member of HITRAN committee (2010-present)

Member of Virtual Atomic and Molecular Data Centre (VAMDC) (2010-present)

Member of IEEE (2016-present)

California Institute of Technology Postdoctoral Scholar at JPL (1999-2001)

University of Arizona, Department of Chemistry, (1995–1999)

Education: Ph.D., Chemistry, University of Arizona (1999); B.S., Chemistry, University of Wisconsin (1995); B.S., Mathematics, University of Wisconsin (1995)

Beginning with microwave spectroscopy of organometallic compounds, Brian's Ph. D. work involved measurement and analyses of highly precise rotational transition frequencies of molecules in cold molecular beams. At JPL he has recorded and analyzed microwave, millimeter, submillimeter, far-infrared, mid-infrared and near-infrared spectra of both astrophysical and atmospheric molecules while incorporating state-of-the-art hardware and software spectrometers. He has participated in seven field campaigns for deployment of submillimeter instruments onboard stratospheric balloons. He is responsible for measurements of molecular line-shape parameters for earth science sensing and astro-chemicals. He has built a field ready THz spectrometer for in-situ gas sensing and is currently developing a highly compact low-mass, low power version with similar capabilities. He administrates and is the primary contributor to the JPL spectral line catalog used throughout the spectroscopy and remote sensing communities.

Brian's mentoring and leadership skills have been honed through interaction with senior research scientists, research scientists, scientists, postdoctoral fellows, graduate students and undergraduates. At JPL he has served as group supervisor to scientists and technologists performing laboratory and field studies and served as mentor to five postdoctoral fellows and advised three others who worked heavily in his laboratory. He has also hosted a half dozen graduate students whose research partially overlapped with the JPL spectroscopy laboratory and directly mentored six undergraduate researchers.

Brian serves on both the MLS and OCO-2 Science teams. He has participated in mission proposals as PI, instrument lead and as a science Co-I. He has participated in NASA, R&TD and SBIR review panels and regularly reviews scientific manuscripts for both spectroscopy and instrumentation.

Principle Investigator Experience

PICASSO – Spectrometer-on-a-Chip (2014-date)

STOCOM – Oxygen A-band Spectroscopy (2015- date)

UARP/ACLAB – Spectroscopy for Atmospheric Research (2005 – date)

APRA – Measurements of State-to-State Collision Rates for Water (2006 – 2013)

ASTID – Submillimeter Spectroscopic Gas Analysis for Life Detection (2008 – 2012)

ADAP – Millimeter and Submillimeter Spectral Line Catalog (2008 – 2011)

Herschel – Laboratory Spectroscopy and Analysis for Herschel (2008 – 2010)

1. Drouin, B.J., A. Tang, E. Schlecht, E, Brageot, Q.J. Gu, Y. Ye, R. Shu, M.C.F Change and Y. Kim, "A CMOS millimeter-wave transceiver embedded in a semi-confocal Fabry-Perot cavity for molecular spectroscopy", *J. Chem. Phys.* 145(7) 074201, 2016.
2. Drouin, B.J., D.C. Benner, L.R. Brown, M.J. Cich, T.J. Crawford, V.M. Devi, A. Guillaume, J.T. Hodges, E.J. Mlawer, D.J. Robichaud, F. Oyafuso, V. J. Payne, K. Sung, E.H. Wishnow, S. Yu, "Multispectrum analysis of the Oxygen A-band." *J. Quant. Spectrosc. & Radiat. Trans.* 2016
3. Drouin, B.J., V. Payne, F. Oyafuso, K. Sung, E. Mlawer, "Pressure broadening of oxygen by water", *J. Quant. Spectrosc. & Radiat. Trans.*, 133 190-198 2014.
4. Drouin, B.J., S. Yu, B. M. Elliott, T. J. Crawford, C. E. Miller, "High resolution spectral analysis of oxygen. III. Laboratory investigation of the airglow bands", *J. Chem. Phys.* 139, 144301, 2013.
5. Drouin B.J., J.C. Pearson, S. Yu, H. Gupta "Characterization and use of a 1.3-1.5 THz multiplier chain for molecular spectroscopy." (invited paper) *IEEE-TST* 3(3) 314-321, 2013.
6. Drouin B.J. "Isotopic Spectra of the Hydroxyl Radical" *J. Phys. Chem. A* 117(39) 10076-10091, 2013.
7. Drouin, B.J., L. Wiesenfeld, "Low-Temperature water-hydrogen-molecule collisions probed by pressure broadening and line shift", *Phys. Rev. A* 86, 022705, 2012.
8. Drouin, B.J., H. Gupta, S. Yu, C.E. Miller, H.S.P. Mueller, "High resolution spectral analysis of oxygen. II. Rotational spectra of $^1\Delta_g$ O₂ isotopologues", *J. Chem. Phys.* 136, 024305, 2012.
9. Drouin, B.J., K. Cooper, R. Dengler, M. Chavez, W. Chun, T. Crawford. "Submillimeter wave spectrometry for in-situ planetary science" Aerospace Conference, 2012 IEEE, 1-4, 2012
10. Drouin B.J., S. Yu, J. C. Pearson, H. Gupta, "Terahertz Spectroscopy for Space Applications, 2.5-2.7: THz Spectra of HD, H₂O and NH₃" *Journal of Molecular Structure* Special Issue on THz Spectroscopy, 1006, 2-12, 2011.
11. Drouin B.J., S. Yu, "Acetylene Spectra near 2.6 THz" *Journal of Molecular Spectroscopy* 269(2), 254-256, 2011.
12. Drouin B.J., J.C. Pearson, M.J. Dick, Reply to "Comment on 'Collisional cooling investigation of THz rotational transitions of water'" *Physical Review A*, 82(3) 036704, 2010.
13. Drouin B.J., S. Yu, C.E. Miller, H.S.P. Mueller, F. Lewen, S.Bruenken, H. Habara, "Terahertz spectroscopy of oxygen, O₂, $^3\Sigma_g$ and $^1\Delta$ electronic states", *Journal of Quantitative Spectroscopy and Radiative Transfer*, 111, 1167–1173, 2010.
14. Drouin B.J., S. Yu, J.C. Pearson, H.S.P. Mueller, "High resolution spectroscopy of CH₃D and $^{13}\text{CH}_3\text{D}$ ", *Journal of Quantitative Spectroscopy and Radiative Transfer* 110(18) 2077-2081, 2009.
15. Drouin, B.J., R. R. Gamache, "Temperature Dependent Air Broadened Linewidths of Ozone Rotational Transitions" *Journal of Molecular Spectroscopy*, 251(1-2), 1-3, 2008.
16. Drouin B.J., K. Cooper, R.A. Stachnik, J.C. Pearson. "Submillimeter wave spectroscopy and the search for life on planets." Infrared, Millimeter and Terahertz Waves, 2008. IRMMW-THz 2008. 33rd International Conference on, 1-3, 2008.
17. Drouin, B.J., "Temperature dependent pressure induced linewidths of O₂ and $^{18}\text{O}^{16}\text{O}$ transitions in nitrogen, oxygen and air", *Journal of Quantitative Spectroscopy and Radiative Transfer*, 105 (3): 450-458, 2007.
18. Drouin, B.J., "Submillimeter measurements of N₂ and air broadening of hypochlorous acid," *Journal of Quantitative Spectroscopy and Radiative Transfer*, 103 (3): 558-564, 2007.
19. Drouin, B.J., J. C. Pearson, A. Walters, V. Lattanzi "THz Measurements of Propane" *Journal of Molecular Spectroscopy*, 240 (2): 227-237, 2006.
20. Drouin, B. J., F.W. Maiwald, "Extended THz measurements of nitrous oxide, N₂O," *Journal of Molecular Spectroscopy*, 236 (2): 260-262, 2006.
21. Drouin, B. J., C. E. Miller, J. L. Fry, D. T. Petkie, P. Helminger, I. Medvedev, "Submillimeter measurements of isotopes of nitric acid," *Journal of Molecular Spectroscopy*, 236 (1): 29-34, 2006.
22. Drouin B. J., F.W. Maiwald, J. C. Pearson, "Application of cascaded frequency multiplication to molecular spectroscopy," *Review of Scientific Instruments*, 76 (9): Art. No. 093113, 2005.

23. Drouin B.J., J. L. Fry, C. E. Miller, "Rotational spectrum of cis-cis HOONO", *Journal of Chemical Physics*, 120 (12): 5505-5508, 2004.
24. Drouin B.J., "Temperature dependent pressure-induced lineshape of the HCl $J = 1 \leftarrow 0$ rotational transition in nitrogen and oxygen", *Journal of Quantitative Spectroscopy and Radiative Transfer*, 83 (3-4): 321-331, 2004.
25. Drouin B.J., J. Fischer, R. R. Gamache, "Temperature dependent pressure induced lineshape of O₃ rotational transitions in air", *Journal of Quantitative Spectroscopy and Radiative Transfer*, 83 (1): 63-81, 2004.
26. Drouin B.J., C. E. Miller and E. A. Cohen, "Further investigations of the submillimeter spectrum of ClO", *Journal of Molecular Spectroscopy*, 207(1), 4-9, 2001.
27. Drouin B.J., C. E. Miller, H. S. P. Muller and E. A. Cohen, "The rotational spectra, isotopically independent parameters, and interatomic potentials for the X₁ $^2\Pi_{3/2}$ and X₂ $^2\Pi_{1/2}$ states of BrO", *Journal of Molecular Spectroscopy*, 205(1), 128-138, 2001.
28. Drouin B.J., J. J. Dannemiller and S. G. Kukolich, "Structural characterization of 'syn' and 'anti' - allyltricarbonylbromide, analyses of rotational spectra, quadrupole coupling and density functional calculations", *Inorganic Chemistry*, 39(4), 827-835, 2000.
29. Drouin B.J., J. J. Dannemiller and S. G. Kukolich, "The gas-phase structure of chloroferrocene from microwave spectra", *Journal of Chemical Physics*, 112(2), 747-751, 2000.
30. Drouin B.J. and S. G. Kukolich, "Microwave spectra and the molecular structure of tetracarbonylethyleneiron", *Journal of the American Chemical Society*, 121(16), 4023-4030, 1999.
31. Drouin B.J. P.A. Cassak and S. G. Kukolich, "Microwave measurements of rhenium quadrupole coupling in cyclopentadienyl rhenium tricarbonyl", *Journal of Chemical Physics*, 108(21), 8878-8883, 1998.
32. Drouin B.J. S.G. Kukolich, "Molecular structure of tetracarbonyldihydroiron: Microwave measurements and density functional theory calculations", *Journal of the American Chemical Society*, 120(27), 6774-6780, 1998.
33. Drouin B.J. N. E. Gruhn, J. F. Madden, S.G. Kukolich, M. Barfield, R.S. Glass, "Gas-phase conformational analysis of 1,4,7-trithiacyclononane", *Journal of Physical Chemistry A*, 101(48), 9180-9184, 1997.
34. Drouin B.J. T. G. Lavaty, P. A. Cassak , S.G. Kukolich "Measurements of structural and quadrupole coupling parameters for bromoferrocene using microwave spectroscopy", *Journal of Chemical Physics*, 107(17) 6541-6548, 1997.
35. Drouin B.J. P. A. Cassak, P. M. Briggs, S.G. Kukolich "Determination of structural parameters for the half-sandwich compounds cyclopentadienyl thallium and cyclopentadienyl indium and indium quadrupole coupling for cyclopentadienyl indium using microwave spectroscopy", *Journal of Chemical Physics*, 107(10), 3766-3773, 1997.
36. Drouin B.J. P. A. Cassak, S. G. Kukolich, "Measurements of structural and quadrupolar coupling parameters for chloroferrocene using microwave spectroscopy", *Inorganic Chemistry*, 36(13), 2868-2871, 1997.

Brian Drouin - Peer-reviewed Non-first Author Publications

36. Yu, S., J.C. Pearson, B.J. Drouin, C.E. Miller, K. Kobayashi and F. Matsushima, "Terahertz spectroscopy of ground state HD¹⁸O." *J. Molec. Spectrosc.* 328, 27-31, 2016.
37. Jacquinet-Husson, N. et al. "The 2015 edition of the GEISA spectroscopic database", *J. Molec. Spectrosc.* 327, 31-72, 2016.
38. Wu, D.L., J-H. Yee, E. Schlecht, I. Mehdi, J. Siles, B.J. Drouin, "THz limb sounder (TLS) for lower thermospheric wind, oxygen density, and temperature", *J. Geophys. Res. Space Phys.*, 121(7) 7301-7315, 2016.
39. Benner, D.C., V.M. Devi, K. Sung, L.R. Brown, C.E. Miller, V.H. Payne, B.J. Drouin, S. Yu, T.J. Crawford, M.A.H. Smith, A.W. Mantz, M.A.H. Smith, "Line parameters including temperature

- dependences of self- and air-broadened line shapes of $^{12}\text{C}^{16}\text{O}_2$: 2.06- μm region” *J. Quant. Spectrosc. & Radiat. Trans.* 2016.
40. Devi, V. M., D.C. Benner, K. Sung, L.R. Brown, T.J. Crawford, C.E. Miller, B.J. Drouin, V.H. Payne, S. Yu, M.A.H. Smith, A.W. Mantz, R.R. Gamache, “Line parameters including temperature dependences of self- and air-broadened line shapes of $^{12}\text{C}^{16}\text{O}_2$: 1.6- μm region” *J. Quant. Spectrosc. & Radiat. Trans.* 177, 117-144, 2016.
41. Dubernet, M. L., B. K. Antony, Y. A. Ba, *et al.* “The virtual atomic and molecular data centre (VAMDC) consortium”, *J. Phys. B*, 49(7), 074003, 2016.
42. Muller, H.S.P., B. J. Drouin, J. C. Pearson, M. H. Ordu, N. Wehres, F. Lewen, “Rotational spectra of isotopic species of methyl cyanide, CH_3CN , in their $v_8=1$ excited vibrational states”, *Astron. & Astrophys.*, 586 (A17), 2016.
43. Ye, Y., B. Yo, A. Tang, B. Drouin, Q.J. Gu, “A High Efficiency E-band CMOS Frequency Doubler with a Compensated Transformer-Based Balun for Matching Enhancement”, *IEEE Micr. And Comp. Lett.* 26(1), 40-42, 2016.
44. Yu, S., J.C. Pearson, B.J. Drouin, T. Crawford, A.M. Daly, B. Elliott, T. Amano, “Rotational spectroscopy of vibrationally excited N_2H^+ and N_2D^+ up to 2.7 THz.” *J. Molec. Spectrosc.* 314, 19-25, 2015.
45. Daly, A.M., B.J. Drouin, J.C. Pearson, K. Sung, L.R. Brown, A. Mantz, M.A.H. Smith, “The v_{17} band of $\text{C}_2\text{H}_5\text{D}$ from 770 to 880 cm^{-1} ”, *J. Molec. Spectrosc.* 314, 19-25, 2015.
46. Shu R., A. Tang, B. Drouin, Q.J. Gu “A 54-84 GHz CMOS SPST Switch with 35 dB Isolation”, accepted *IEEE RFIC* 2015.
47. Mercury, M., B. Drouin, E. Brageot, R. Beatty, R. Green, P. Mouroulis, G. Stephens, R. Duren, F. Rogers, H. Rosen, D. Gerwe “Monitoring Earth’s Shortwave Reflectance: LEO and GEO System Architectures”, *IEEE Aerospace* 2015.
48. C. Duan, M. Carvajal, S.Yu, J.C. Pearson, B.J. Drouin and I. Kleiner, “THz extended spectrum of the monodeuterated methyl formate (DCOOCH_3)”, *Astron. & Astrophys.* 576, A39, 2015.
49. Mueller H.S.P., L.R. Brown, B.J. Drouin, J.C. Pearson, I. Kleiner, R.L. Sams, K. Sung, M.H. Ordu, F. Lewen, Rotational spectroscopy as a tool to investigate interactions between vibrational polyads in symmetric top molecules: Low-lying states $v_8 \leq 2$ of methyl cyanide, CH_3CN . *J. Molec. Spectrosc.* 312, 22-37, 2015.
50. Daly, A. M., Drouin, P. Groner, S. Yu, J.C. Pearson, Analysis of the rotational spectrum of the ground and first torsional excited states of monodeuterated ethane, $\text{CH}_3\text{CH}_2\text{D}$, *J. Molec. Spectrosc.* 307, 27-32, 2015.
51. Yu, S. B.J. Drouin, C.E. Miller, High resolution spectral analysis of oxygen. IV. Energy levels, partition sums, band constants, RKR potentials, Franck-Condon factors involving the $\text{X } ^3\Sigma^-_\text{g}$, $a^1\Delta_\text{g}$ and $b^1\Sigma^+_\text{g}$ states *J. Chem. Phys.* 141(17), 174302 2014.
52. Lopez A., B. Tercero, Z. Kisiel, A. M. Daly, C. Bermudez, H. Calcutt, N. Marcelino, S. Viti, B.J. Drouin, I.R. Medvedev, C. F. Neese, L. Pszczolkowski, J. L. Alonso, J. Cernicharo, Laboratory Characterization and Astrophysical Detection of vibrationally Excited States of Vinyl Cyanide in Orion KL. Detection of the isocyanide species, *A&A*, 572, A44 2014
53. Ting W-J, C-H Chang, S-E Chen, H-C Chen, J-T. Shy, B. J. Drouin, A. M. Daly, Precision frequency measurement of N_2O transitions near 4.5 μm and above 150 μm , *Journal of the Optical Society of America – B*, 31(8), 1954-1963, 2014.
54. Hase, F., B.J. Drouin, C.M. Roehl, G.C. Toon, P.O. Wennberg, D. Wunch, T. Blumenstock, F. Desmet, D.G. Feist, P. Heikkinen, M. De Maziere, M. Rettinger, J. Robinson, M. Schneider, V. Sherlock, R. Sussmann, Y. Te, T. Warneke, C. Weinzierl, Calibration of sealed HCl cells used for TCCON instrumental line shape monitoring, *Atmos. Meas. Tech.* 6(12), 3527-3537, 2013.
55. Daly, A.M., B.J. Drouin, S. Yu, Submillimeter measurements of the Criegee intermediate CH_2OO , in the gas phase, *J. Molec. Spectrosc.* 297, 16-20, 2014.

56. Motiyenko R.A., V.V. Ilyushin, B.J. Drouin S. Yu, L. Margules, Rotational spectroscopy of methylamine up to 2.6 THz. *A&A*, 563, Article Number: A137, 2014.
57. Coudert, L.H, B.J. Drouin, B. Tercero and J. Cernicharo, J.-C. Guillemin, R. A. Motiyenko, L. Margules, First astrophysical detection, terahertz spectrum, and data base for the monodeuterated species of methyl formate HCOOCH₂D, *Ap. J.*, 779(2), 119, 2013.
58. Ilyushin, V.V., Smirnov, I.A., E.A Alekseev, L. Margules, R.A. Motiyenko, B. Drouin. "Spectroscopy of the ground, first and second excited torsional states of acetaldehyde from 0.05 to 1.6 THz", *J. Molec. Spectrosc.*, 295, 44-50, 2013
59. Yu, S., J.C. Pearson, B.J. Drouin, "Terahertz spectroscopy of water in its second triad." *J. Molec. Spectrosc.* 288, 7-10, 2013.
60. Smirnov, I.A., E.A Alekseev, V.V. Ilyushin, L. Margules, R.A. Motiyenko, B. Drouin. "Spectroscopy of the ground, first and second excited torsional states of acetaldehyde from 0.05 to 1.6 THz", Physics and Engineering of Microwaves, Millimeter and Submillimeter Waves (MSMW), 2013 International Kharkov Symposium on, 495-497, 2013
61. Rothman L.S. et al. "The HITRAN 2012 Molecular Spectroscopic Database", *J. Quant. Spectrosc. & Radiat. Trans.* 130, 4-50, 2013.
62. Ilyushin, V., C.P. Endres, F. Lewen, S. Schlemmer, B. J. Drouin, "Submillimeter wave spectrum of acetic acid", *J. Molec. Spectrosc.* 290, 31-41, 2013.
63. Cohen, E.A., B.J. Drouin, "Submillimeter wave spectrum of sulfuric acid, H₂SO₄", *J. Mol. Spectrosc.* DOI:10.1016/j.jms.2013.04.008, 2013.
64. Faure A., L. Wiesenfeld, B.J. Drouin, J. Tennyson, "Pressure broadening of water and carbon monoxide transitions by molecular hydrogen at high temperatures." *J. Quant. Spec. Radiat. Trans.* 116, 79-86, 2013.
65. Cohen, E.A., B.J. Drouin, L.R. Brown, J.J. Oh " Terahertz and infrared spectra of carbonyl fluoride, COF₂: Vibration-rotation analyses of the four lowest bands, 2v₆, and v₆ hot bands; ¹³COF₂ ground state and v₆ band." *J. Quant. Spectrosc. Radiat. Trans.* 114, 13-19, 2013.
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67. Kisiel Z., L. Pszczołkowski, B.J. Drouin, C.S. Brauer, S. Yu, J.C. Pearson, I.R. Medvedev, S. Fortman, C. Neese, "Broadband rotational spectroscopy of acrylonitrile: Vibrational energies from perturbations", *J. Molec. Spectrosc.* 280, 134-144, 2012.
68. Yu S., J. C. Pearson, B. J. Drouin, M-A. Martin-Drumel, O. Pirali, M. Vervloet, L.H. Coudert, H. S.P. Müller, S. Brünken, "Measurement and analysis of new terahertz and far-infrared spectra of high temperature water" *J. Molec. Spectrosc.* 279, 16-25, 2012.
69. Yu S., C.E. Miller, B.J. Drouin, H.S.P. Mueller, "High resolution spectral analysis of oxygen. I. Isotopically Invariant Dunham Fit for the X ³S_g⁻, a ¹A_g, b¹S_g⁺ States", *J. Chem. Phys.* 136, 024304, 2012.
70. De Luca, M, H. Gupta, D. Neufeld, M. Gerin, D. Teyssier, B.J. Drouin, J.C. Pearson, D.C. Lis, R. Monje, T.G. Phillips, J.R. Goicoechea, B. Godard, E. Falgarone, A. Coutens, T.A. Bell, "Herschel/HIFI Discovery of HCl⁺ in the Interstellar Medium" *Ap. J. Lett.* 751(2) L37, 2012.
71. Gupta, H. B.J. Drouin, J.C. Pearson "The Rotational Spectrum of HCl⁺" *Ap. J. Lett.* 751(2) L38, 2012.
72. Ramos M., B. J. Drouin, "Submillimeter Spectrum of Methyl Bromide (CH₃Br)" *Journal of Molecular Spectroscopy*, 269(2), 187-192, 2011.
73. Pearson J.C., B.J. Drouin, S. Yu, H. Gupta "Microwave Spectroscopy of Methanol between 2.48 and 2.77 THz" *Journal of the Optical Society of America*, 28(10), 2549-2577, 2011.
74. Pearson J., B. Drouin, A. Maestrini, I. Mehdi, J. Ward, R. Lin, S. Yu, J. Gill, B. Thomas, C. Lee, G. Chattopadhyay, E. Schlecht, F. Maiwald, P. Goldsmith, P. Siegel "Demonstration of a room temperature 2.48-2.75 THz coherent spectroscopy source", *Review of Scientific Instruments* 82(9), 093105, 2011.
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76. Cohen, E.A., B.J. Drouin, "THz spectra of Formyl Fluoride, HFCO", *Journal of Molecular Spectroscopy*, 267, 67–70 2011.
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78. Pearson J.C., Mueller H.S.P., Pickett H.M., Cohen E.A., Drouin B.J., "Introduction to submillimeter, millimeter and microwave spectral line catalog", *Journal of Quantitative Spectroscopy and Radiative Transfer* 111(11), 1614-1616, 2010.
79. Yu S., Pearson J.C., Drouin B.J., Sung K., Pirali O., Vervloet M., Martin-Drumel M.A., Endres C.P., Shiraishi T., Kobayashi K., Matsushima F., "Submillimeter-wave and far-infrared spectroscopy of high-J transitions of the ground and v₂=1 states of ammonia." *Journal of Chemical Physics* 133(17) 174317, 2010.
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84. Dick M.J., Drouin B.J., Pearson J.C., "Collisional cooling investigation of THz rotational transitions of water." *Physical Review A* 81(2), 2010.
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87. Muller H.S.P., Drouin B.J., Pearson J.C., "Rotational spectra of isotopic species of methyl cyanide, CH₃CN, in their ground vibrational states up to terahertz frequencies", *Astronomy and Astrophysics*, 506 (3) 1487-1499, 2009.
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